contain a number of organisms. In such a case the vaccine would be left to mature—*i.e.* to get rid of these organisms—which it will do in a few days at the outside. As soon as such organisms can no longer be demonstrated in plate cultures, or as soon as the exact period at which they disappear has been absolutely determined, the glycerinated vaccine may be used by the operator, who may have full confidence that no secondary or untoward conditions, which can in any way be attributed to impurity of the vaccine lymph, will arise.

In view of these facts, and of the splendid results that have been obtained in Paris, Brussels, Berlin, Cologne, Dresden and Geneva—the vaccine Institutes in which cities were specially visited and reported upon by Sir Richard Thorne Thorne and Dr. Monckton Copeman—and in view, also, of the recommendation of the Royal Commission on Vaccination, all who take an interest in this question (and the number of these is far greater than many people imagine) will hail with delight any measure brought forward by the Government to facilitate the preparation and encourage the use of glycerinated calf lymph, especially wherever it is found necessary to apply the compulsory clauses of the Vaccination Act, and also for vaccination generally.

Perhaps one of the main advantages adduced in favour of vaccination with calf lymph is that the animals may in the first instance be carefully selected, so that only such as are of sound constitution and good family history need be employed; but even then, under the old system, owing to the outlay involved if the calves were killed at once and not used for food, a post-mortem examination could not be obtained, or thorough inspection of the organs made. It was, therefore, not possible for the vaccinating officer to state that there was no disease in the animal. Now that such a large amount of lymph can be obtained from a single calf, it would scarcely be justifiable to neglect this post-mortem inspection; consequently, as the lymph should not be used for a few days after it has been taken and made into an emulsion, the medical officer is able to assure both himself and his clients, that the animal from which the special lymph he is using has been taken is absolutely free from flaw or blemish, whilst the after-treatment of the lymph with glycerine enables him to certify that the effects of accidental contamination from outside are completely neutralised.

It is somewhat humiliating to us as a practical nation to find that a method worked out theoretically by an Englishman should have received attention, and been applied practically in almost every important European country before it has been thought necessary to draw attention to it at home. Still, we are glad that at last Government has been brought to see its duty in this matter, and to make preparations for acting up to the light it has received.

For the information of our readers we may quote Sir Richard Thorne Thorne's conclusions, drawn up after visiting the establishments to which reference has already been made:—

"(1) It is desirable that vaccination, both primary and secondary, carried out under the auspices of the Government, should be performed exclusively with vaccine lymph direct from the calf.

"(2) There will probably be advantage in retaining, for a time at least, the system of calf-to-arm vaccination at the Board's Animal Vaccine Station for such parents and others as may specially desire it, and for the purposes of comparing its results with those following the use of calf lymph preserved in one or another way.

"(3) The distribution of calf vaccine from the National Vaccine Establishment should be limited to glycerinated or similar preparations of lymph and pulp material, in air-tight tubes, or other glass receptacles.

"(4) To give effect to the above it will be requisite that the Board's Animal Vaccine Station should be reorganised, both as regards construction and administration. Notably will it be requisite that it should include a properly equipped laboratory, under the direct supervision of a bacteriological expert."

It is to be hoped that in any legislative measure which may be formulated and passed, due effect will be given to each of these four conclusions, although from many points of view it would appear desirable that the second recommendation should be made to cover a comparatively short period, as most people who have studied the question are now fully of the opinion that calf-to-arm vaccination has no advantages over vaccination with glycerinated lymph, and few parents who are likely to express any opinion at all, may be expected to ask for calf-to-arm vaccination of their children.

We look upon this document as one of the most important that has been published from the Department for some time, and we heartily recommend a perusal of its contents to those who are in any way interested in the study of the vaccination question.

NOTES ON SOME VOLCANIC PHENOMENA IN ARMENIA.

As we descended from the central mountains of Armenia towards the south along the road from Akstafa to Erivan, we suddenly came upon a beautiful sheet of water lying glassy and restful in the lap of the mountains. Those on the left, sloped down to its shore with every diversity of valley, creek and headland, and with gently moulded outlines which told of subaerial waste, and gave the impression of a mountain land the base of which the waters had but recently begun to bathe. From the heights on which we stood the lake seemed to follow a somewhat narrow sinuous course, which suggested the idea that we were looking on a dammed-up valley. But it could not be the submerged end of a long valley invaded by the sea, for we were still between 6000 and 7000 feet above sea-level. On the right, beyond the lake, conical hills, often nicked at the summit, with long ridges radiating from them, rose in strong contrast to the more ancient rocks of the northern slopes, and suggested plainly by their geographical outline a volcanic region which had been so recently active that there had not yet been time for its distinctive features to have been obliterated.

Soon we wound our way round the north-western end of the lake, and found that we had to cross its principal outlet, and then immediately descend rapidly into the valley of the Araxes. Here, then, we might hope to see some reason for this strange holding up of such a vast body of water on the edge of the mountain land.

As we turned round to the right beyond the little village of Elenofka we found the passage barred by long moraine-like ridges. We had just seen snow-covered summits and glaciers in the Caucasus, a little further north, and moraines, telling of the former much greater extension of those glaciers. We asked ourselves whether similar conditions might not have produced glaciers and moraines here also on the slopes of the Armenian mountains? But when we reached the first of the ridges we found that it was not a moraine at all, but a lava-flow with scoriaceous surface and more solid rock within. The stream with its equalised flow had cut but a very small gap in these barriers, one after another of which had been thrown forward, and had built up a mass which, from the physical geography of the country, we inferred must be thousands of feet in thickness. What the depth of Lake Gokcha was we were not able to ascertain, but it runs for forty-three miles along the base of the mountains and widens out in places to a breadth of twenty miles. To save room our diagram (Fig. 1) is taken across the narrow western end, so that it does not indicate the proportion this enormous body of water bears to the size of the valley below. Should that lake by any great shock be suddenly let out—not an improbable catastrophe—what a terrible deluge would sweep the plain of the Araxes; and, if the lake were wholly or partly drained, what a history of the gradual heaping up of waters on the flanks of an active volcanic region might be studied in its depths.

Here we saw not a mountain valley dammed, but the whole foot of a mountain region enclosed by volcanic ejectamenta having their origin along a belt of country lying a little off and in front of the high ground. From this the inference is obvious that the outlet was not always where we crossed it, and we were therefore prepared to find here and there curious conditions of the rock pointing to a different line of exit for the percolating and overflowing water.

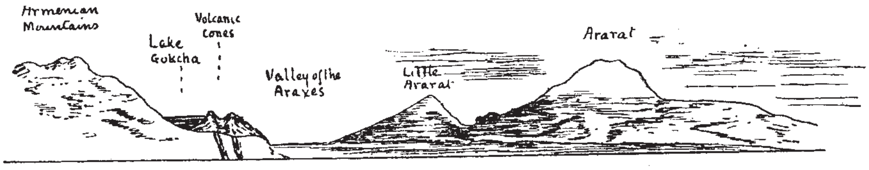

FIG. 1.—Diagram to explain the mode of occurrence and origin of Lake Gokcha.

What struck us most in examining the outflowing stream at Elenofka was its very small volume considering the extent of the lake that feeds it, and we could see no evidence of any considerable difference of level between the late summer's flow and the winter's flood waters. The stream filled its channel up to its reedy green bank, and no bare beds of sand and gravel or heaps of torrent débris suggested that it ever rose any higher. Perhaps when the waters do rise, they find their way through broken or scoriaceous rock to other outlets.

Driving on through ridge and tumbled crag of brown and black cindery rock—the great barrier of lava that holds back the lake—we suddenly came to the southern flank. We looked out through an opening in the lava over the rich valley of the Araxes, and first caught sight of Ararat rising grandly alone into the soft southern sky. Distance did not dwarf its 17,000 feet; but whether it was active at the same time that the Elinofka volcanoes were locking up Lake Gokcha, I cannot say. Perpetual snow now covers this hill of ancient fires. There it has stood for ages, looking down on the region where tradition carries us back to the earliest homes of civilised man.

As we descended from the great masses of lava around Lake Gokcha, we suddenly came upon a most interesting and suggestive section, where the road winds under a cliff, partly natural and partly cut back for the road itself, so as to exhibit now a face of newly-bared rock. In this we saw alternations of dark green or brown-black obsidian, and a white product of decomposition of volcanic rock standing in vertical planes (see Fig. 2). The white rock is, especially in the upper part of the cliff, apt to be broken up into a kind of breccia made up of pieces of all sizes and shapes. The first impression produced by the section would be that it consisted of a number of bands of obsidian alternating with a coarse agglomerate of fragments of one and the same kind of decomposed igneous rock, and all turned on end by subsequent movement. But an examination of the ground soon showed that view to be untenable, because the section was cut through the terminal margin of a lava-flow which had come down from the great volcanic group forming the southern rim of Lake Gokcha (see Fig. 3, in which the arrow indicates the direction of flow). The obsidian bands are therefore at right angles to the bedding.

Another view was therefore suggested, namely, that the obsidian was injected or found its way along vertical fissures in the crushed and brecciated rock of an earlier flow. But had this been so, there seemed no reason to limit the injection to the vertical planes. The molten liquid mass would have penetrated in all directions through the fractured rock. Besides, an examination of the rock in detail showed that the obsidian was not injected, for it occurred in isolated masses in the midst of the white porcelanous or powdery rock. The plates assumed a fan-shaped arrangement in places, as if their position had been determined by joints converging downwards. The mode of occurrence of the rock suggested the true explanation of the phenomenon. The white rock was decomposed obsidian. The whole mass was a quickly cooled lava traversed by shrinkage joints at right angles to the cooling surfaces, and roughly parallel to the line of flow. Water followed the cracks, acted on the silicates, and changed the glassy lava to the white chalk-like mass in which bands of obsidian, preserved between the joints, still remained samples of what the whole rock once was.

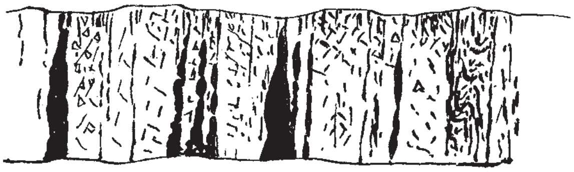

FIG. .

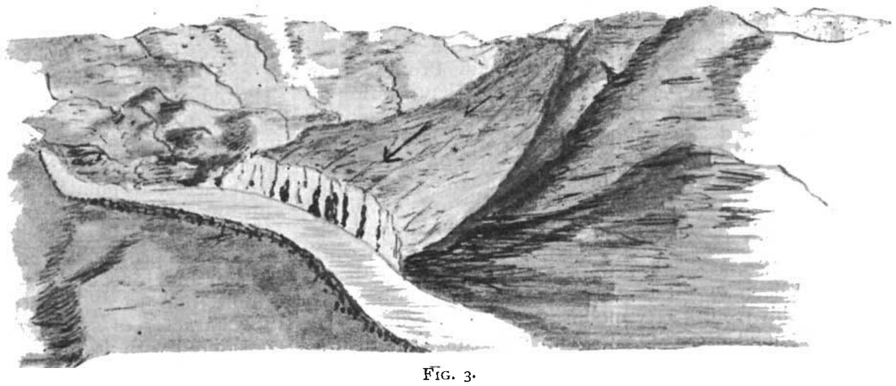

FIG. 3.

A similar change may be observed at Obsidian Cliff in the Yellowstone Park in America, where the same alternation of bands of decomposed and sound obsidian may be seen as in the Armenian section, though not on such an extensive scale. The same process picks out by decomposition the spheroidal shells, which are invisible in the sound part. An analogous process may also be seen in the grand cañon of the Yellowstone River, where the rhyolites have been weathered into a white or yellowish, mealy-textured rock along the great fissure, which allowed a freer passage to, and still emits, in diminished quantities at the bottom of the gorge, heated water and steam from the dying-out volcanic furnace below.

So along the Armenian lava-flow water easily got in from the surface, or followed the longitudinal cracks in the rapidly cooled rock, and, being itself heated by the process, acted upon the silicates, and carried off the more soluble portions. A diminution in volume accompanied the process, and the reduced rock broke up.

May be the old valley down which this lava flowed was an ancient outfall of Lake Gokcha before its rim had been built up as high as it now stands. Perhaps at one time some of the water of the lake found its way through fissured masses to lower levels, and carried on the work of destruction within the rock itself.

We want many more facts respecting this most interesting district—we would like to know the depth of the lake, the direction of any observed lines of fissure, and if there is any evidence of the waters of the lake having ever been suddenly drained off into the valley of the Araxes. We hope, therefore, that Mr. Loewinson Lessing, whose knowledge and skilful arrangements enabled us to see so much of the district, and whose courtesy and thoughtfulness made our excursion so pleasant, may be able to carry on the work for which he is so well qualified, and will communicate to the world the result of his further investigations.

T. MCKENNY HUGHES.

PERIODIC ORBITS.

FOR some years past, Prof. G. H. Darwin has been engaged on the numerical solution of a particular case of the problem of three bodies, and at different times he has given some account of the progress he has made. He has now collected his very extensive material, relating to both the mathematical methods employed and the discussion of the numerical results, into one compact summary under the title of "Periodic Orbits," which appears in *Acta Mathematica*, vol. xxi. The special case treated by Prof. Darwin refers to one of three classes into which M. Poincaré has divided the periodic solutions of this problem. In this class, the motion is entirely in two dimensions, and the excentricity of the planet's orbit is very small; but Prof. Darwin further supposes the perturbed body to have infinitely small mass, and the planet's orbit to be absolutely circular. The discussion of even this one class has had to be restricted in the course of the work, on account of the heavy arithmetical labour which the method of tracing the orbits by mechanical quadratures involved. Retrograde orbits have not been considered, and the motion of superior planets is still engaging Prof. Darwin's attention. Some thirty examples of periodic orbits have, however, been examined; and though the author may speak of his results very modestly, there is no doubt but that his conclusions will be welcomed as a most interesting contribution to the study of celestial mechanics.

Prof. Darwin defines a periodic orbit as one in which a third body can continually revolve so as always to present the same character relative to the two other bodies of the system. These orbits are not necessarily confined to a single revolution round the primaries, or round any other point in space, but the difficulty of the determination of the path increases with the number of circuits described, and on that ground the present treatise is confined to the examination of "simple periodic orbits," or those which are re-entrant after a single circuit, though loops may, and do, occur in the orbit. In the system considered, the distance between the sun and the principal planet, here called Jove, is taken as unity, and the ratio of the mass of the sun to that of the planet as 10 : 1. This hypothesis differs considerably from the actual circumstances prevailing in our system, but it offers the advantage of exaggerating all the phenomena of perturbation, and permits the clear exhibition of the deductions in diagrams that are easily appreciated. Some of the stellar systems may offer conditions more nearly parallel to those here assumed. A looped orbit has been suggested in the case of one of the components of ζ Cancri, though possibly with insufficient data, and in some other cases, the presence of a disturbing body seems likely to produce an orbit of very irregular form.

We have accustomed ourselves to consider the relations of superior and inferior planets and of satellites to be fixed and definite, but Prof. Darwin traces the conditions under which these forms cease to be permanent, and when consequently the third body of a system can assume the characteristic motion of either an inferior planet or a satellite. With a particular value for the constant of relative energy, it is possible for both kinds of planetary and satellite motion to become confused, and for a body which originally started in one way to exhibit the peculiar motion of either of the other two. Prof. Darwin began his numerical work by an assumed case in which it was possible for an inferior planet and satellite to interchange their parts. The satellite was made to start at right angles to a line joining the sun and Jove, at a distance of 1·08 from the sun, Jove's distance being unity. The resulting orbit is fully drawn and shows how the body hangs in the balance, between the two centres, before the elliptic form of the orbit asserts itself, as the body approaches the sun. Starting the satellite from a conjunction remote from the sun, but at slightly different distances from Jove, it is found that the resulting orbits show a great diversity of character, which cannot always be foreseen. Perhaps the most remarkable curve in this family arises when the satellite starts at a point 1·095 from the sun. After making a loop, the satellite recrosses the line of conjunction and moves directly towards the planet, so that it is impossible to determine its subsequent path without very accurate computation. "I do not think," says Prof. Darwin, "any one could have conjectured how the body should have been projected so as to fall into Jove." The positions which give rise to periodic orbits are shown by the distances from the sun at which the curve meets the line of conjunction after one complete circuit. If for two selected points of projection, the curve returns to this line at places alternately nearer to and more remote from the sun than those from which it originally started, then there must be some point intermediate between these selected points at which the curve will be re-entrant. Other forms of orbits giving rise to distinct families, have been computed, and drawn, when the satellite is projected from points intermediate between the sun and Jove, and also from conjunction on the side remote from Jove. Most of these orbits do not possess the character of stability, a point which the author has considered with as much care as the form of the orbit itself. It has been questioned whether all orbits are not essentially unstable, if the number of revolutions be sufficiently great. The result of the present investigation is to show that orbits may be stable if the perturbation of Jove by the planet can be neglected. This is the only approximation that Prof. Darwin has permitted himself, and he remarks "that for a very small planet the instability must accordingly be a very slow process, and I cannot but believe that the whole history of a planetary system may be comprised in the interval required for the instability to render itself manifest."